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In-situ measurement of window performance

Various field tests can determine the integrity of the window and the quality of its installation

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Long-term, in-situ performance of windows is of great concern to building designers and window manufacturers. In many buildings, windows are the largest contributor to building heat loss. If the in-situ window heat loss or air leakage is greater than the value used in the design stage, the heating system may not be able to maintain comfort conditions.

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As a result, the engineer may be faced with the difficult task of determining whether the heating system design is inadequate, the windows are performing below specification or the installation is of poor quality. Even if there are no complaints about comfort, the engineer, architect and building owner may want to verify that the windows they got are what they specified.

In the past, window performance could be determined by simply counting the number of glazings. Today, however,

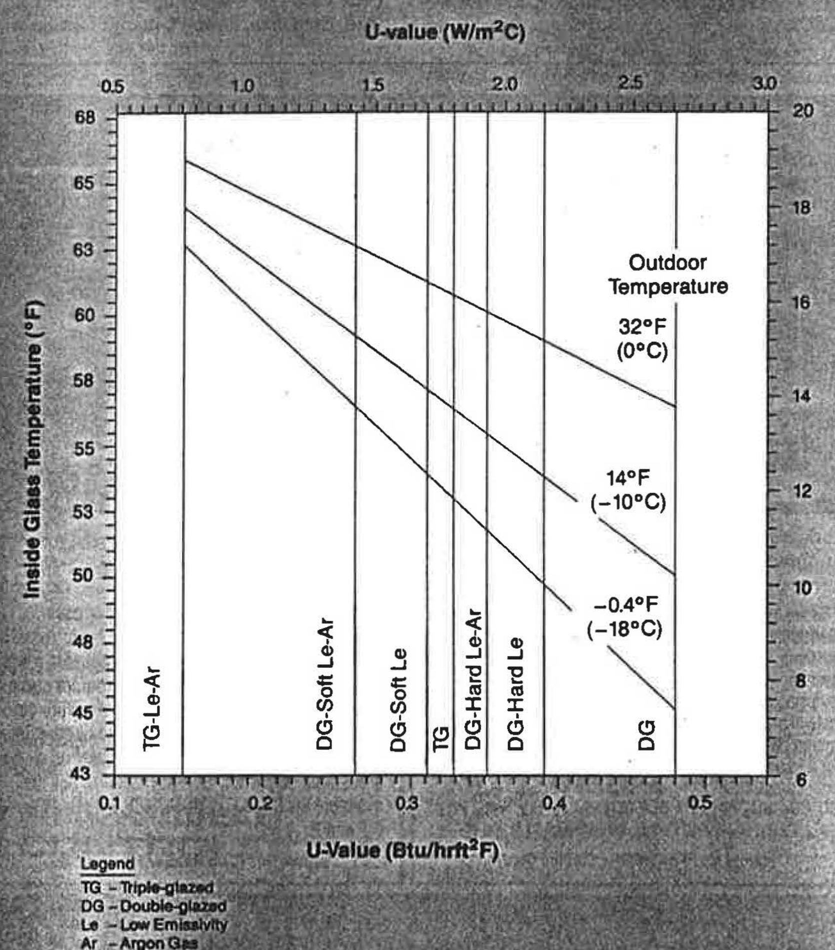

Figure 1. Interior glass temperature as a function of window U-value.

the use of low-emissivity coatings, argon gas fills, low-conductivity spacers and new frame materials and designs means that a window cannot be judged just by looking at it.

While there are many laboratory methods for testing window thermal resistance, air leakage and other physical properties, the performance of the installed window may be significantly different from the results. This article describes current and developing methods for assessing in-situ window heat loss and air leakage.

Window heat loss

There are many techniques for assessing in-situ window heat loss, ranging from simple measurements to infrared thermography and computer simulation. Perhaps the simplest method is to measure the outdoor temperature and the inside glass temperature at the center of the window. The lower the window heat loss is, the higher the glass temperature will be.

Figure 1 depicts the interior glass temperature as a function of window U-value for several outdoor temperatures at an indoor temperature of 70°F (21°C). The vertical lines show the expected glass temperature for the more common double-glazed (DG) and triple-glazed (TG) window systems. These glazing systems can use either a "soft" (emissivity 0.09) or "hard" coat (emissivity 0.35), in conjunction with either air or argon (Ar) gas fill. (Some new hard coats have emissivities below 0.2 and can be represented by the line labelled TG.)

By comparing the measured glass temperature to the figure, the coatings and gas fills used in the window should be apparent. This technique can only be used when it is reasonably cold outside and there is little solar radiation incident on the window. The interior glass temperature can vary slightly because of fluctuations in the wind, sky conditions and interior film coefficient. As such, this technique cannot distinguish minor variations in coating emissivity or gas concentration. The same technique can be applied to the edge-of-glass and window frame to determine the presence of thermal breaks, low-conductivity spacers and other frame improvements.

A finite-difference computer program (Carpenter 1989) can also be used to predict window frame and edge-of-glass heat loss and temperatures. By comparing the computer predictions to on-site measurements, it may be possible to identify frame characteristics.

The accuracy of computer simulation to determine window heat loss has been

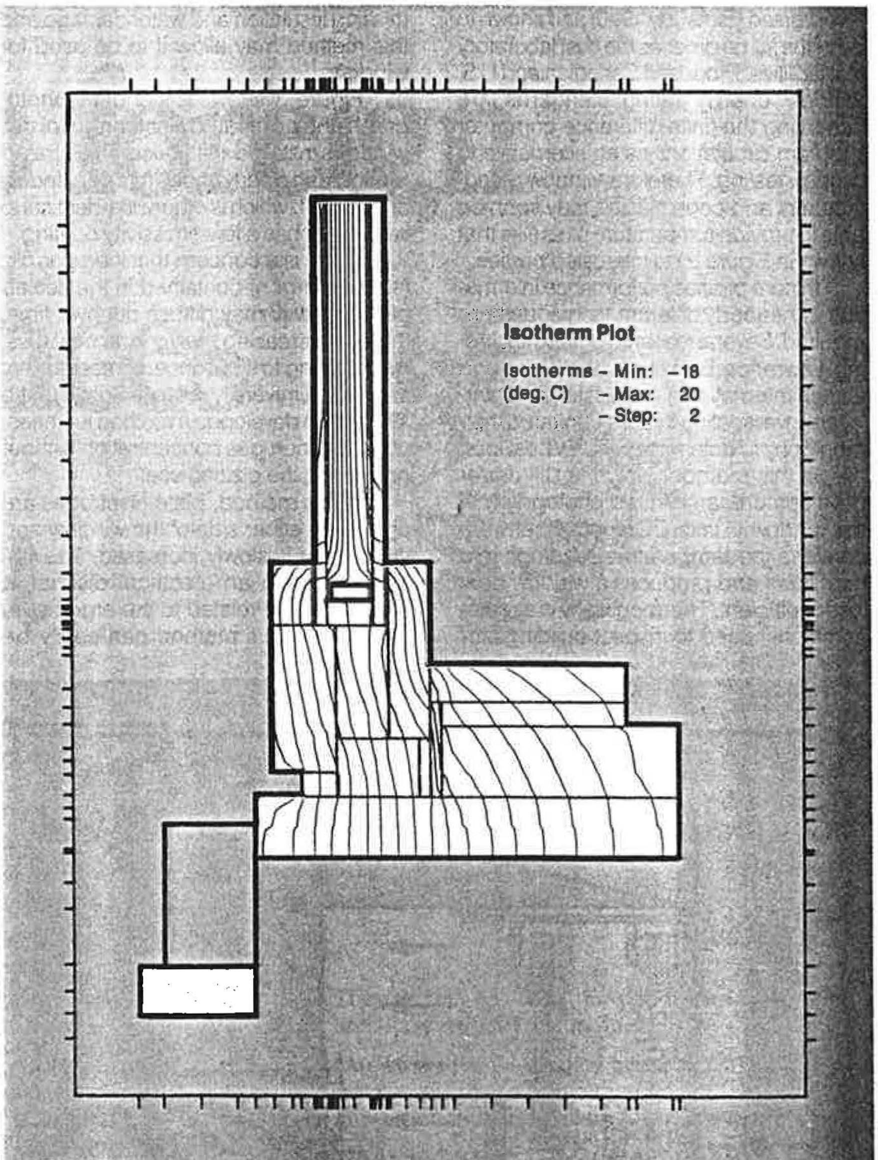

Figure 2. Computer-generated window temperature plot.

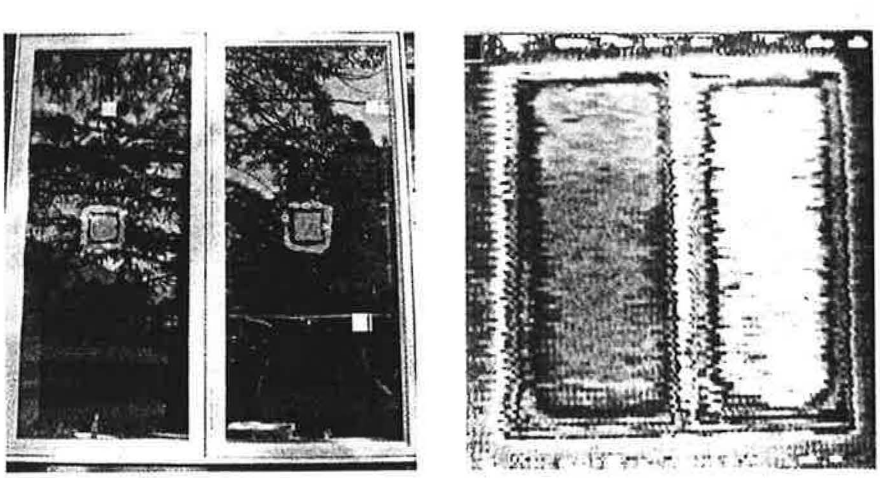

Figure 3. Conventional and infrared photographs of double-glazed and double-glazed low-e windows.

investigated (Elmahdy 1990) and shown to be of the same order as the best laboratory test facilities. Proposed Canadian and U.S. window energy rating standards are accepting the finite-difference computer program simulations as an alternative to window testing. Therefore, window manufacturers and code officials may soon be able to provide temperature plots (like that shown in *Figure 2*) to interested parties.

If more precise performance information is needed, different techniques are required. Several research groups (including Lawrence Berkeley Laboratory and Ortech International, Mississauga, Ontario) are investigating the use of infrared thermography to determine window heat loss.

In this method, which is still under development, an infrared photograph of the window is taken. Computer software converts the temperature readings into heat flows and produces a window heat loss coefficient. Thermography is already commonly used to inspect buildings for missing insulation and water damage and this method may allow it to be used for windows.

Figure 3 shows a standard photograph and an infrared photograph of two windows installed in a house. The infrared photograph clearly shows that the window on the right, which is otherwise identical to its partner, has a low-emissivity coating.

There is a concern that inert gas fills (such as argon) contained in the sealed glazing cavity may diffuse out over time, thereby increasing the window heat loss. Responding to this concern, researchers at Acadia University in Nova Scotia (Latta 1990) have developed a method for measuring the inert gas concentration without destroying the glazing seal.

In this method, plate electrodes are placed on either side of the window and the voltage is slowly increased. The voltage at which an electrical discharge occurs can be related to the argon concentration. This method can easily be used in the field to measure argon concentrations to within 0.3 percent. This concept, although still under development, is expected to be commercialized soon by an insulated glass manufacturer.

Window air leakage

Cold drafts are one of the most common occupant complaints. The source of the draft may be the air distribution system, leakage through window seals or air leakage around the window. The airtightness of most windows is tested to ASTM-E783 (CAN3-A440 in Canada).

This laboratory test, which is done over a range of pressure differences but at no temperature differential, provides a reasonable means of comparing the air leakage characteristics of factory-produced windows. Damage during shipping, worn weatherstripping, thermal warpage and poor installation can cause significant increases in air leakage.

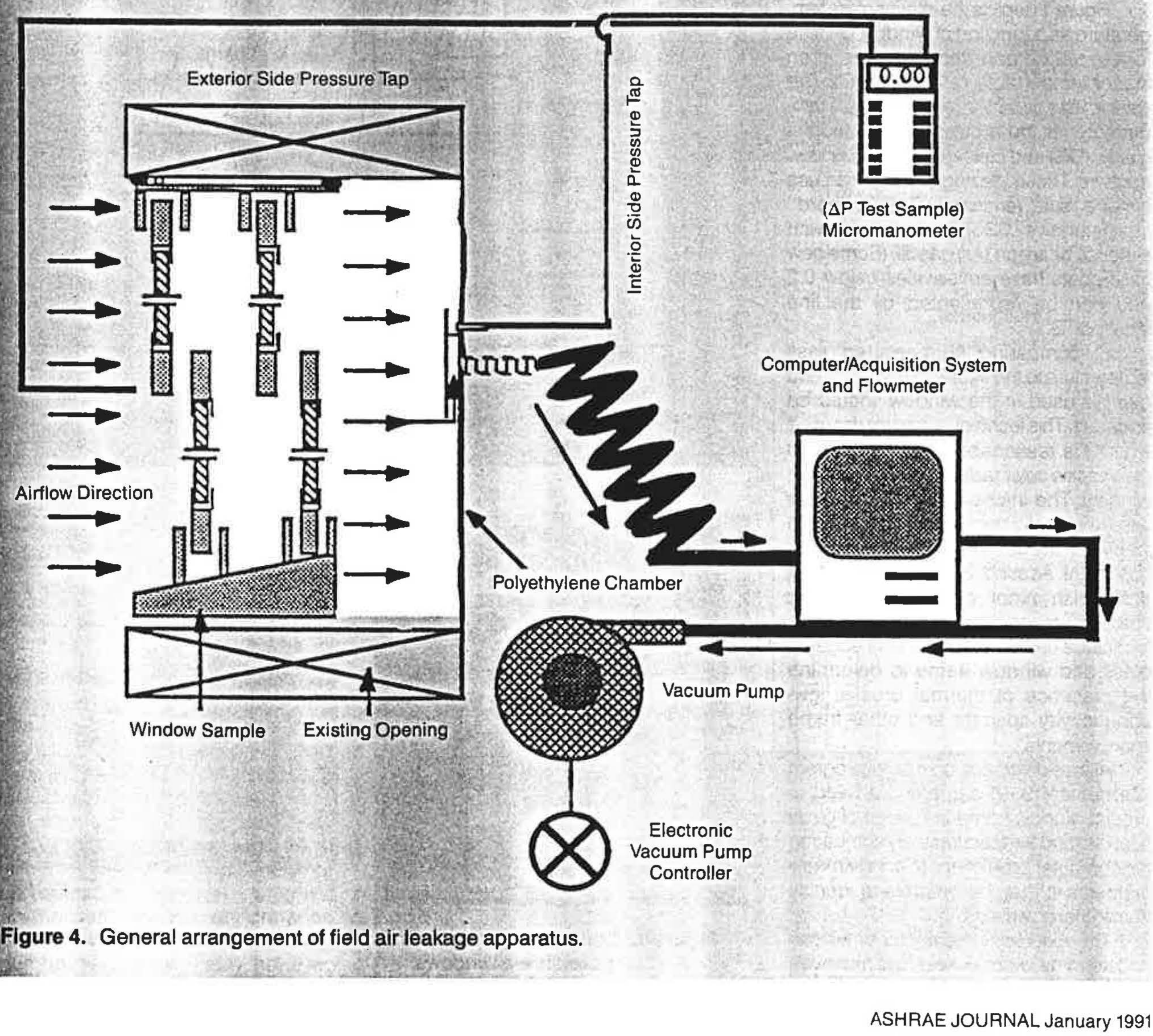

Figure 4. General arrangement of field air leakage apparatus.

Window performance

Table 1. Measured Window Air Leakage[1]

Window	1	2	3
Frame Type	Wood	Wood	Vinyl/Wood
Installation	No Fill	Loose-Fill	Tight-Fill
Window Leakage @1.56 lb/ft^2 (75 Pa)			
Laboratory	0.003 (.019)	0.002 (.012)	0.003 (.018)
Field Test	0.003 (.015)	0.006 (.032)	0.003 (.015)
Window/Wall Interface Leakage @1.56 lb/ft^2 (75 Pa)	3.9 (21.8)	2.9 (15.9)	0.68 (3.8)

[1] *In cfm/ft of crack (m^3/h per m of crack).*

The airtightness of the window and the window/wall interface can be field-tested using the inexpensive apparatus shown in *Figure 4*. With this commercially available system, a plastic sheet is first taped to the window frame, and a vacuum pump is used to induce a pressure differential across the window. The vacuum pump flow rate is related to the pressure differential to assess the airtightness of the window.

The test is repeated but, this time, with the plastic sheet taped to the wall instead of the window frame. The increase in flow rate that occurs is due to the window/wall interface and is a measure of the installation quality.

This technique was recently tested on three different picture windows (two wood and one vinyl) installed in three different ways (Ortech 1989). These windows were first tested in a commercial laboratory for air leakage, then shipped to the job site and installed.

The field-test air leakage apparatus was used to measure the window and window/wall interface air leakages. The windows were installed by the same contractor using three different techniques. In the first installation, the cavity between the window and wall was left empty and standard interior and exterior trim applied. For the second and third installations, the cavity was filled with loosely-packed glass-fiber and tightly-packed glass-fiber, respectively, and trim applied.

Table 1 shows the results from the three tests. All three windows were significantly below the Canadian window standard (CAN3-A440) maximum acceptable air leakage of 0.045 cfm/ft of crack length (0.25 m^3/hr per meter of crack length). The small change in air leakage when measured at the job site showed that the windows maintained their air seal integrity through the shipping and installation process.

The surprising result is that air leakage through the window/wall interface is at least two hundred times greater than that through the window. A poor installation job can increase cavity air leakage by a factor of six. These results show the value of in-situ testing in identifying problems.

Conclusions

The advent of new window enhancements that are essentially invisible increases the need for in-situ testing of window performance. Window heat loss can be estimated by comparing site-measured temperatures to glazing and frame temperature plots.

Infrared thermography and electrical discharge tests hold promise as accurate methods for determining window characteristics. Window and window/wall interface air leakages can readily be measured at the site. All of these tests can often provide valuable information on the integrity of the window and the quality of the installation. ■

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